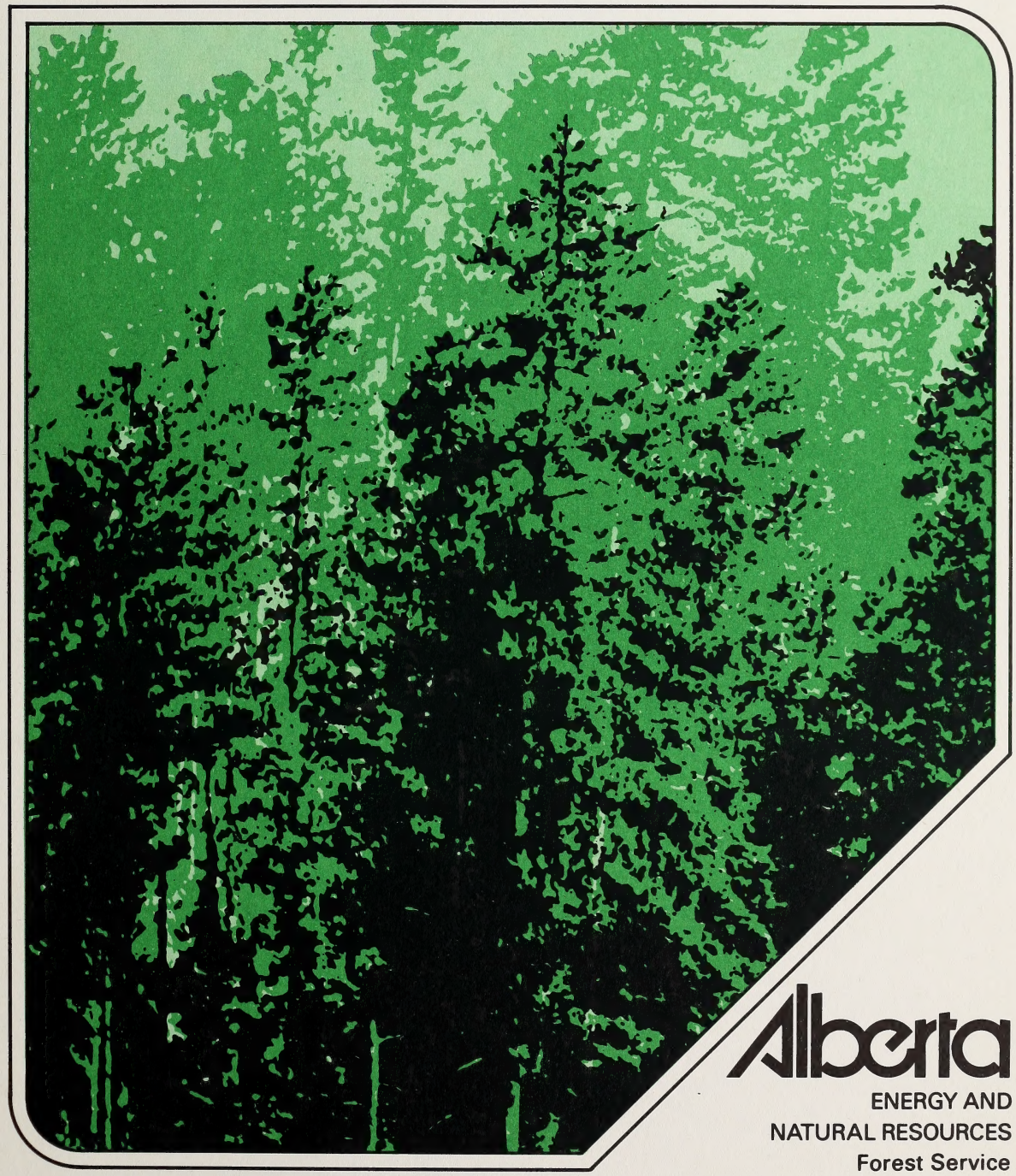
Evaluation of Trees and Shrubs for Coal Mine Reclamation in the Eastern Slopes



Alberta

ENERGY AND
NATURAL RESOURCES
Forest Service

EVALUATION OF TREES AND SHRUBS FOR COAL MINE RECLAMATION IN THE EASTERN SLOPES:

A Summary of Alberta Forest Service Field Demonstration Plantings 1973-1977

by

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ABSTRACT

Between 1973 and 1977 approximately 15000 bareroot and containerized tree and shrub seedlings, involving 29 species, were planted on a wide range of coal-mine disturbances in the Rocky Mountain Eastern Slopes of Alberta. The major objective was to determine the suitability of each species for use in coal-mine reclamation.

Assessments of some or all the plantings were made in 1973, 1977, 1978, 1979, 1980, and 1984. By 1984 most species had low survival rates and poor growth, which suggests they are poorly adapted to the test site environments. Possible exceptions are caragana, Colorado spruce, green alder, Siberian larch, and white spruce which showed potential for use on wind-protected Subalpine sites; also, caragana, lodgepole pine, and white spruce showed potential for use on protected Montane sites. Lodgepole pine and white spruce did well in some plots in the Coal Valley Region and are recommended for use on mine sites in the Boreal Foothills and Boreal Uplands Ecoregions.

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All plantings were established under the supervision of Jiri Selner, with the exception of TM-11 which was established by Paul King. Jiri Selner supervised the assessment of the plots in 1973. The assessments in 1977 were conducted by Jiri Selner and Paul King with assistance from Jim Bell and Sam Takyi. Milo Mihajlovich and I conducted the assessments in 1978. Paul King assessed the TM-5, TM-9, and TM-11 plantings in 1979. I am solely responsible for the 1984 assessments.

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1. INTRODUCTION

Recognizing a need for woody plants in coal-mine reclamation in the Eastern Slopes, the Alberta Forest Service began field testing commercially available tree and shrub species in 1973. Between 1973 and 1977 approximately 15000 bareroot and container seedlings, involving 29 species, were planted on a wide range of coal-mine disturbances. These plantings were the first large-scale attempt to test commercially available trees and shrubs for reclamation in the Eastern Slopes.

Most of the plantings were established as demonstration plots. Each plot contained a single species, and that species usually was not planted elsewhere on the site. Details on plot establishment methods are given in Mihajlovich and Russell (1980), Selner (1973), and Selner et al. (1977) and are summarized in this report.

The aim of the present study was to assess the survival, height, and vigor of each planting. Previous assessments of some or all of the plantings had been made in 1973, 1977, 1978, 1979, and 1980. The results are reported in Alberta Forest Service (unpublished data), Mihajlovich and Russell (1980), King (1980), Selner (1973, 1974), and Selner et al. (1977). This report summarizes the current and past results and discusses their practical implications for reclamation.

2. STUDY AREAS

The plantings were established on active and abandoned coal mines in nine locations in the Rocky Mountain Foothills of Alberta (Fig. 1). The legal locations and elevations of the planting sites are given in Appendix 1.

The plantings were established on a variety of spoil materials ranging from fine-textured, highly erodable mudstones and shales to coarse-textured overburden and coal waste. Selner (1973) collected and analyzed spoil samples from 29 selected plots in 1973. Most samples were low in available nitrogen and phosphorus. Available potassium levels ranged from low to high (40-228 ppm). The samples were non-saline (< 0.6 s/m) and ranged in pH from 5.0 to 8.6.

The most northerly plantings were at Coal Valley, Sterco, and Lovett on the Luscar Sterco (1977) Ltd. mining lease. These sites are in the Boreal Uplands Ecoregion (of Strong and Leggat 1981) close to the boundary with the Boreal Foothills Ecoregion. Steep rolling foothills typify the undisturbed terrain. Post-fire forests dominated by lodgepole pine (Pinus contorta), aspen (Populus tremuloides), and balsam poplar (Populus balsamifera) characterize the surrounding uplands. Black spruce (Picea mariana) dominates the poorly drained lowlands. Year-long meteorological data is available at Nordegg (el. 1320 m), approximately 83 km southeast of Coal Valley. The mean annual temperature is 0.7°C and mean temperatures for January and July are -14.1°C and 12.6°C, respectively. Nordegg receives 555 mm of precipitation annually, of which 181 mm is snowfall. The seasonally

Fig. 1 LOCATION OF THE PLANTING SITES

operated meteorological station at nearby Lovett (el. 1445 m) receives an average of 85, 111, 98, and 94 mm of precipitation for May, June, July, and August, respectively, and has a mean July temperature of 12.9°C (Alberta Environment 1982).

The other plantings are in more mountainous terrain in the southern foothills around Blairmore. The plantings at Grassy Mountain, Nez Perce, Coleman Collieries office, and Coleman plant are in the Montane Ecoregion. Open stands of Douglas fir (Pseudotsuga menziesii) and grassland dominated by rough fescue (Festuca scabrella) and oat grass (Danthonia sp.) characterize the warm, dry slopes (Strong and Leggat 1981). The closest meteorological station is at Coleman (el. 1341 m). The mean annual temperature is 3.2°C and mean temperatures for January and July are -9.4°C and 14.6°C, respectively. This station receives 569 mm of annual precipitation, of which 218 mm is snowfall. The Montane planting sites are expected to have warmer winter temperatures than those of the other ecoregions, due in part to chinook winds. Grassy Mountain appeared to be the most exposed and windy planting site in the study.

The highest elevation planting sites were at Tent Mountain and Racehorse in the Subalpine Ecoregion. The forests surrounding Racehorse and the lower planting site on Tent Mountain are dominated by lodgepole pine. The higher elevation site on Tent Mountain is close to tree-line and is surrounded by open stands of alpine fir (Abies lasiocarpa), engelmann spruce (Picea engelmannii), and some whitebark pine (Pinus albicaulis). The closest high elevation meteorological station to Tent Mountain is the seasonally operated Ironstone Fire Tower (el. 2073 m), which has a mean July temperature of 11.9°C and receives 253 mm of precipitation from June through September. The Livingstone Lookout (el. 2170 m) is closest to Racehorse. The mean July

temperature is 11.4^{oC} and precipitation from June through September is 190 mm.

3. METHODS

3.1 Establishment of Plantings

3.1.1 1973 Plantings

In spring 1973 51 plots of bareroot lodgepole pine, bareroot white spruce, and containerized white spruce seedlings were established on various coal mines in the foothills. Fifteen plots were established from 10 to 17 May at Sterco, Coal Valley, and Lovett and 36 plots from 26 May to 1 June on Grassy and Tent Mountains. Each plot contained 100 seedlings spaced at 1 m intervals. Wooden stakes marked the location of each plant; after 12 years most stakes were broken and scattered around the plots. All planting was done by hand, probably with a Swedish tree-planting mattock. The planting stock came from Alberta Tree Nursery and Horticulture Centre, formerly Oliver Provincial Tree Nursery (OPTN). Most plots were overseeded with a legume or grass-legume cover crop. Further details on establishment methods are given in Appendix 1 and Selner (1973).

3.1.2 1977 Plantings

In spring 1977 18 commercially available deciduous tree and shrub species were planted as bareroot stock on various coal mines in the foothills. The planting locations were Coal Valley, Tent Mountain, Racehorse, Nez Perce, Coleman Collieries Office, and Coleman Collieries Plant. Past assessment data is available for 67 plots. The plots varied in size, number of plants, and time of planting. All planting was by hand, probably with a Swedish tree-planting mattock. All stock was obtained from the Prairie Farm

Rehabilitation Nursery (PFRA) in Indian Head, Saskatchewan. Some plots were overseeded with a legume or grass-legume seed mixture. Further details on plot establishment are given in Appendix 1.

3.1.3 TM-5

In mid-June 1976 six tree and shrub species were planted as bareroot stock in mine spoils on Tent Mountain. The seedlings were hand planted with a Swedish tree-planting mattock and spaced at 1 m intervals. The plots varied in size and number of plants. The age of the planting stock was 2 - 0 for deciduous species, 2 - 2 for white spruce, and 2 - 3 for Colorado spruce. All stock was obtained from PFRA. Further details on establishment are given in Appendix 1 and Selner et al. (1977).

3.1.4 TM-9

In fall 1976 six tree and shrub species were planted as container stock in mine spoils on Tent Mountain. Ferdinand Spencer-Lemaire containers were used for all species except Douglas fir, which was grown in Hillson containers. The age of the stock at planting time was 20 months, except for Siberian larch and Douglas fir which were 30 months. All planting stock was obtained from OPTN. The seedlings were hand planted using a Swedish tree-planting mattock and spaced at 1 m intervals. Establishment details are in Selner et al. (1977) and Appendix 1.

3.1.5 TM-11

In June 1977 aspen and green alder container seedlings were planted on topsoil-covered coal overburden on Tent Mountain. Three hundred seedlings of each species were established in a randomized complete block trial with three replications. The planting stock was grown in Ferdinand Spencer-Lemaire containers at OPTN for one year before outplanting by hand with a Swedish

tree-planting mattock. The plots were broadcast fertilized with 225 kg/ha of 10-20-10 fertilizer at planting time. Establishment details are given in Mihajlovich and Russell (1980) and Appendix 1.

3.2 Assessment of Plantings

Prior to 1984 the seedlings were assessed for survival and vigor by assigning them to one of four categories: 1 = surviving well; 2 = surviving, but not doing well; 3 = mortality expected; and 4 = dead. The living plants in TM-5, 9, and 11 were also assessed for height, height growth, and in 1979 for dieback and browse damage (Mihajlovich and Russell 1980, King 1980).

From 14 to 24 August 1984 the plots were assessed by counting the number of living plants in each plot and measuring the maximum stem height and height growth of each living plant. In addition, the presence and degree of stem dieback, leaf chlorosis, insect damage, rodent browse damage, ungulate browse damage, disease, sexual reproduction, and vegetative reproduction on each plant were assessed using the following ranked categories:

stem dieback: 0 = no dieback; 1 = slight dieback, only on the upper 1/3 of plant; 2 = moderate dieback, affecting upper 2/3; 3 = heavy dieback, affecting > 2/3

leaf chlorosis: 0 = leaves not chlorotic; 1 = slight chlorosis; 2 = moderate chlorosis; 3 = heavy chlorosis

insect damage: 0 = no damage; 1 = up to 1/3 of leaves damaged; 2 = 1/3 - 2/3 of leaves damaged; 3 = > 2/3 of leaves damaged

rodent browse damage: 0 = no damage; 1 = < 1/3 stem girdled; 2 = 1/3-2/3 stem girdled; 3 = > 2/3 stem girdled

ungulate browse damage: 0 = no damage; 1 = lightly browsed, < 1/3 of stems damaged; 2 = moderately browsed, 1/3-2/3 of stems damaged; 3 = heavily browsed, > 2/3 of stems damaged

disease: 0 = no outward signs of fungal infection; 1 = plant infected, fruiting bodies present

sexual reproduction: 0 = no evidence of flowering orfruiting; 1 = flowers and/or fruits present

vegetative reproduction: 0 = no evidence of sprouting from rhizomes, roots or stolons; 1 = sprouting present (excludes sprouting at base of mother plant)

Maximum stem height was measured by placing a metre stick at the base of the plant and bending the tallest stem to the stick. Annual height growth on deciduous seedlings (excluding larch) was the distance from the previous year's highest point of stem growth to the current year's highest point of stem growth. These two points were sometimes on separate branches. On coniferous species five-year height growth was approximated by measuring the distance on the central stem from the top to the fifth whorl of branches down from the top. The frequency of plants showing leaf desiccation, wind damage, split leaders, and/or aborted terminal shoot buds was also determined for some species.

4. RESULTS AND DISCUSSION

4.1 1973 Plantings (Table 1 and Appendix 2)

Nine plots of lodgepole pine and 20 plots of white spruce were assessed in 1984 after 12 growing seasons. Survival was 34% for white spruce and 16% for lodgepole pine. Generally, survival and height of both species were greater at Lovett and Sterco than Grassy Mountain. The tallest plants assessed in 1984 were growing in coal spoils at Sterco. Grassy Mountain occurs at higher elevation and is more wind exposed than Lovett and Sterco. Many of the plants on Grassy Mountain were wind damaged (see plates 6 and 7); however, no wind damage was observed on plants at Lovett or Sterco.

Of the three species/stock combinations that were planted, bareroot white spruce had the highest survival after 12 growing seasons with 44%; bareroot pine was next with 16%; and containerized white spruce was lowest with 15%. Bareroot stock had better overall survival than container stock (34% versus 15%). Since the handling methods and condition of the stock at planting time are unknown, little can be concluded.

4.2 1977 Plantings (Table 2 and Appendix 3)

In May 1977 18 deciduous trees and shrubs were planted as bareroot stock in mine spoils on six sites. Survival was generally low, due in part to the poor condition of the stock at planting time (pers. com. field staff). In the plots that could be found, overall survival was 40% after the first growing season, 28% after the second, and 21% after the eighth.

Table 1

SUMMARY OF SPECIES SURVIVAL RATE, HEIGHT, AND FIVE-YEAR HEIGHT GROWTH IN PLOTS ESTABLISHED IN 1973

Site	Species/ Stock Type[1]	Survival (%) 1973	1978	1980	1984	Mean Height (cm) 1984	Mean 5-yr Height Growth (cm/5 yr) 1980-84
Lovett (el. 1372 m)	Pl/br.	96	94	92	D[2]	D	D
	Sw/br.	99	85	89	86	67	47
	Sw/cont.	79	19	32	D	D	D
Sterco (el. 1433 m)	Pl/br.	89	NA	23	23	191	123
	Sw/br.	95	NA	73	71	166	110
	Sw/cont.	69	NA	27	34	128	94
Grassy Mountain (el. 1585-1890 m)	Pl/br.	45	19	NA	15	58	49
	Sw/br.	70	31	NA	27	29	23
	Sw/cont.	38	11	NA	10	29	22

[1] Pl = lodgepole pine; Sw = white spruce; br. = bareroot stock; cont. = container stock
[2] D = plots destroyed; NA = plots not assessed

Table 2

SUMMARY OF SPECIES SURVIVAL RATE, HEIGHT, AND ANNUAL HEIGHT GROWTH IN PLOTS ESTABLISHED IN 1977

Species	Survival (%) 1977	1978	1984	Mean Height (cm) 1984	Mean Annual Height Growth (cm/yr) 1984
acuteleaf willow	45	NF[1]	NF	NF	NF
American elm	44	27	NF	NF	NF
amur maple	2	1	NF	NF	NF
balsam poplar	30	22	< 1	81	23
Bassford willow	41	23	18	26	19
buffaloberry	64	52	D	D	D
caragana	53	40	42	57	15
green ash	52	28	2	17	17
laurel willow	5	NF,NA	NF	NF	NF
Manitoba maple	25	4	2	38	11
mixed poplar	29	25	15	29	9
mixed willow	49	43	32	34	21
native willow	29	0	NF	NF	NF
northwest poplar	51	41	11	39	17
Russian olive	25	22	70	51	15
Siberian elm	44	46	NF,D	NF,D	NF,D
vernirubens poplar	27	0	NF,D	NF,D	NF,D
Walker poplar	18	0	NF	NF	NF

[1] NF = plots not found; D = plots destroyed; NA = plots not assessed

Some of these plantings could not be located for assessment in 1984. Although it is probable that plant mortality was very high in the unlocated plots, there is no data to substantiate this. Table 2 summarizes the survival data only for those plots that could be found each year. Thus the survival percentages may be based on different plots in different assessment years.

4.3 TM-5 Plantings (Tables 3 and 4)

In spring 1976 six woody species were planted as bareroot stock in mine spoils on Tent Mountain. After two growing seasons Colorado spruce, white spruce, Manitoba maple, and Asian rose had good survival (> 80%), Siberian larch had fair survival (51%), and red elder had poor survival (19%). Survival dropped only slightly from the second to fourth seasons for most species. After the ninth season, however, all Asian rose plants were dead and only Colorado spruce and white spruce had > 50% survival. All species suffered dieback after the second growing season but increased in height from the third to ninth seasons. After nine seasons Siberian larch was the tallest species (73 cm) and Manitoba maple the shortest (12 cm).

4.4 TM-9 Planting (Tables 5 and 6)

In fall 1976 six woody species were planted as container stock in mine spoils on Tent Mountain. After two growing seasons Siberian larch had the highest survival (92%) and speckled alder the lowest (21%). After eight seasons Siberian larch was tallest (mean height of 55 cm) and had the highest survival (84%) while speckled alder was shortest (mean height of 17 cm) and had the lowest survival (14%). Due to confusion over the location of some of the plots, green alder, American elm, and paper birch were not assessed in 1984. However, all three species were low growing due to heavy dieback.

Table 3

SPECIES SURVIVAL RATE AFTER TWO, THREE, FOUR, AND NINE GROWING SEASONS IN TRIAL TM-5 ON TENT MOUNTAIN

Species	Survival (%)			
	1977	1978	1979	1984
Asian rose	82	69	35	0
Colorado spruce	94	94	90	86
Manitoba maple	87	86	71	11
red elder	19	19	13	3
Siberian larch	51	49	49	48
white spruce	88	88	84	76

Table 4

SPECIES HEIGHT AND HEIGHT GROWTH IN TRIAL TM-5

Species	Mean Height (cm)			Mean Annual Height Growth (cm/yr)				Mean 5-yr Height Growth (cm/5 yr)
	1977	1978	1984	1977	1978	1979	1984	1980-84
Asian rose	15	10	-	-14	-5	< 1	-	-
Colorado spruce	20	22	43	-3	2	4	NA	NA
Manitoba maple	13	14	12	-16	< 1	< 1	5	NA
red elder	11	12	21	-1	1	< 1	19	NA
Siberian larch	33	37	73	-5	4	4	NA	40
white spruce	21	21	50	-< 1	< 1	4	NA	29

Table 5

SPECIES SURVIVAL RATE AFTER ONE, TWO, THREE, AND EIGHT GROWING SEASONS IN TRIAL TM-9 ON TENT MOUNTAIN

Species	Survival (%) 1977	1978	1979	1984
American elm	62	57	35	NF[1]
Douglas fir	33	30	27	23
green alder	54	51	51	NA
paper birch	57	52	44	NA
Siberian larch	94	92	92	84
speckled alder	20	21	21	14

[1]NF = plot not found; NA = plot not assessed

Table 6

SPECIES HEIGHT AND HEIGHT GROWTH IN TRIAL TM-9 ON TENT MOUNTAIN

Species	Mean Height (cm) 1984	Mean Annual Height Growth (cm/yr) 1977	1978	1979	1984	Mean 5-yr Height Growth (cm/5 yr) 1980-84
American elm	NF	3	-4	-1	NF[1]	NF
Douglas fir	26	2	0	< 1	NA	14
green alder	NA	2	-1	-5	NA	NA
paper birch	NA	2	-3	-2	NA	NA
Siberian larch	55	5	2	2	NA	29
speckled alder	17	2	2	9	5	NA

[1]NF = plot not found; NA = plot or parameter not assessed

4.5 TM-11 Planting (Tables 7 and 8)

In June 1977 aspen and green alder container seedlings were planted in mine spoils which were topdressed with mineral soil on Tent Mountain. After eight growing seasons green alder had 78% survival and a mean height of 19 cm. Aspen had 52% survival and a mean height of 16 cm. Both species had suffered heavy stem dieback and, green alder especially, heavy browse damage by ungulates (see Plates 1 and 5).

4.6 Results by Species

This section summarizes and discusses the results for each species. Each discussion is preceded by a short paragraph on the origin, distribution, ecology, and uses of the species. The introductory material was taken largely from Oosterhuis (1983), Strong and Leggat (1981), and phone conversations with Howard Fox and Bill Schrader at the Prairie Farm Rehabilitation Nursery (PFRA) in Indian Head, Saskatchewan. Scientific species names are given in Appendix 4.

4.6.1 Acuteleaf Willow (Table 2 and Appendix 3)

Acuteleaf willow is a fast-growing, multiple-stemmed tree introduced for shelterbelt planting in Alberta. Acuteleaf willow was planted as bareroot stock in three plots in spring 1977. It survived well for one growing season at Coal Valley (92%) but poorly at Racehorse (38%) and Nez Perce (4%). None of the plots could be relocated for assessment in subsequent years, which suggested a high mortality rate during the first winter.

4.6.2 American Elm (Tables 2, 5, and 6; Appendix 3)

American elm is a native tree in southern Canada. Its range extends from western Newfoundland and Cape Breton Island to central Saskatchewan.

Table 7

SPECIES SURVIVAL RATE AFTER TWO, THREE, AND EIGHT GROWING SEASONS IN TRIAL TM-11 ON TENT MOUNTAIN

Species	Survival (%)		
	1978	1979	1984
aspen	94	86	52
green alder	83	80	78

Table 8

SPECIES HEIGHT AND HEIGHT GROWTH IN TRIAL TM-11 ON TENT MOUNTAIN

Species	Mean Height (cm)			Mean Annual Height Growth (cm/yr)	
	1978	1979	1984	1979	1984
aspen	39	41	16	2	9
green alder	10	16	19	7	5

It grows primarily along rivers in rich, moist, well-drained sandy loam or gravelly soils, where the water table is near the surface.

Four plots of bareroot stock were planted in 1977. Survival after one growing season ranged from 70% at Coal Valley to 12% at the Coleman Office. Overall survival was 44% after the first growing season and 27% after the second season. None of the plots could be relocated for assessment in subsequent years.

American elm was also planted as container stock on Tent Mountain in 1976 (trial TM-9). Survival was 62% after the first growing season but dropped to 35% after the third season. The plots could not be located in 1984, which suggested high plant mortality after the third season.

4.6.3 Amur Maple (Table 2 and Appendix 3)

Amur maple is a small, introduced tree which is used in Alberta for background planting and visual screens. It is popular because of its red fall leaf color. It is susceptible to winter kill in Alberta.

Amur maple was established as bareroot stock in three plots in 1977; however, it did poorly. Its highest survival after one growing season was only 5%. None of the plots could be found for re-assessment in 1984.

4.6.4 Asian Rose (Tables 3 and 4)

Asian rose is a hardy shrub which was introduced from Asia. It is well adapted to a wide range of soils. It is planted in the Canadian prairie mainly for wildlife, including cover for deer and nesting for birds. Sharptail grouse are especially fond of its fruit. It has done well in reclamation plantings on coal mines near Estevan, Saskatchewan (pers. com. Howard Fox, PFRA).

Ninety-nine bareroot seedlings were planted on Tent Mountain in spring

1976 (trial TM-5). Survival was 82% after the second growing season and 69% after the third. Mean height dropped from 15 to 10 cm from the second to third years due to dieback. No living plants were found after the ninth season.

4.6.5 Aspen (Tables 7 and 8; Plate 1)

Aspen is the most widely distributed and abundant tree in Alberta. It is the dominant tree in the Boreal Foothills, and it is abundant in the Montane. It occurs frequently but not abundantly in the Subalpine and occasionally in the Boreal Uplands. It grows best on a well-drained loam; however it is commonly found on a wide variety of soils. In Alberta natural windbreaks of aspen contribute greatly to the protection of farmsteads, crops, and livestock. The bark of aspen is sensitive to injury and bark wounds are readily infected with decay fungi.

Aspen container stock was planted in three plots on Tent Mountain in spring 1977 (trial TM-11). Survival of the 300 seedlings was 94% after two growing seasons and 52% after eight seasons. Every surviving plant in 1984 had moderate to heavy stem dieback and many (34%) had been browsed by ungulates. Dieback and browsing have combined to keep these plants low. Mean plant height in 1984 was only 16 cm. Several plants in 1984 (4%) had reproduced vegetatively by sprouting from rhizomes. A few had copper-red colored leaves, a possible indication of nutrient stress.

4.6.6 Balsam Poplar (Table 2; Appendix 3; Plate 2)

Balsam poplar is native in the Eastern Slopes, where it often grows in moist, well-drained, fluvial soils. It is common in the Boreal Foothills and Montane Ecoregions, but it is rarer at higher elevations. In the past it was occasionally planted in farmstead shelterbelts or as an ornamental.

Plate 1. Aspen container seedling after eight growing seasons in trial TM-11 on Tent Mountain (August 1984). Browsing by ungulates and dieback have kept these plants sparse and low.

Plate 2. Balsam poplar bareroot seedling after eight growing seasons in plot 83 on Tent Mountain (August 1984). This was the only surviving plant found in 1984. Many of the branches have been browsed by ungulates.

Plate 3. Bassford willow bareroot seedling after eight growing seasons in plot 82 on Tent Mountain (August 1984). This plant was growing in coarse-textured spoils and has been damaged by ungulate browsing and dieback.

Plate 4. Caragana bareroot seedling after eight growing seasons in plot 112 at Nez Perce (August 1984). Caragana had a higher survival rate and better height growth than most other deciduous species. Many of the plants produced abundant seed pods in 1984.

Plate 1.

Plate 2

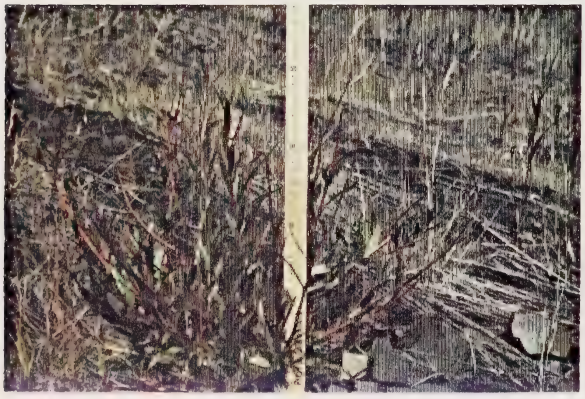

Plate 3.

Plate 4.

Survival in the two plots of bareroot seedlings that were established in 1977 was 30% after one growing season, 22% after two seasons, and < 1% after eight seasons. Since the plots were established in exposed locations on Nez Perce and Tent Mountain, which were above where balsam poplar's normal elevation, the low survival rate might have been predicted. In 1984 only one surviving plant was found of the 340 initially planted. It had stem dieback and moderate browse damage by ungulates.

4.6.7 Bassford Willow (Table 2; Appendix 3; Plate 3)

Bassford willow was introduced probably from Europe for use in farmstead shelterbelts. It was susceptible to winter kill and is no longer produced at PFRA.

Bassford willow was planted as bareroot stock in three plots during May 1977. After eight growing seasons overall survival was 18%. Survival ranged from < 1% at Tent Mountain and the Coleman Collieries Office to 38% at Racehorse. In 1984 all surviving plants had heavy stem dieback and were slightly chlorotic. A few plants (10%) showed slight damage from browsing by ungulates. Mean plant height was 26 cm.

4.6.8 Buffaloberry (Table 2 and Appendix 3)

A native shrub of coulees and river valleys of southern Alberta, buffaloberry is cold hardy, very drought resistant, and tolerant of alkaline soils. It is used in hedgerow and shelterbelt plantings and as an ornamental. It is prized for its silvery foliage.

Buffaloberry was planted as bareroot stock in a single plot at the Coleman Plant in spring 1977. Survival was 64% after the first growing season and 52% after the second in this river valley location. The plot was subsequently destroyed during reclamation activities and could not be assessed

in 1984.

4.6.9 Caragana (Table 2; Appendix 3; Plate 4)

An introduced shrub from Siberia, caragana is planted extensively throughout the Canadian prairies for shelterbelt and hedgerows. It is exceptionally drought and cold hardy and is often planted on the windward side of shelterbelts. Caragana will grow in a wide range of soils, including dry sands, but is sensitive to repeated flooding. It is well adapted to Montane temperatures, as evidenced by its common use as a hedgerow plant in towns in the Crowsnest Pass.

Bareroot caragana seedlings were planted in five plots in May 1977. Reclamation activities destroyed the three plots at the Coleman Plant sometime after the second growing season. Eight-year survival in the remaining two plots was 42%.

While its mean height after eight seasons was only 57 cm, considerably less than would be expected on more protected and fertile sites, caragana was taller and had better survival than all other deciduous species that were tested, with the exception of Siberian larch. After eight seasons 82% of the surviving plants showed some degree of stem dieback, an indication of the harsh conditions on the test sites. Although 56% of the surviving plants produced fruit in 1984, there were no seedlings or young plants in the plots. Thus, the seeds are not viable or they do not germinate and survive.

4.6.10 Colorado Spruce (Tables 3 and 4)

Colorado spruce is native to the Rocky Mountains of Colorado and Utah, where it occurs near streams at high elevations. In Alberta it is used for shelterbelt planting, and is valued as an ornamental because of its attractive blue-green needles.

A single plot of bareroot seedlings was planted on Tent Mountain in 1976 (trial TM-5). After the ninth growing season survival was still high (86%). However 40% of the survivors had dieback on their upper branches, 58% had aborted terminal shoots, and 49% had split leaders. Short internodes and crowded shoot growth over the past few years gave the tops of some plants a krummholtz appearance.

Colorado spruce had the best survival of any species tested on Tent Mountain, but it was not as tall as white spruce or Siberian larch. Its stunted growth is evidence of the harsh climate on this site.

4.6.11 Douglas Fir (Tables 5 and 6)

Douglas fir is a common native tree on shallow, moderately well drained, medium-textured soils in the Montane Ecoregion (Strong and Leggat 1981). The occurrance of Douglas fir and/or limber pine communities serves to distinguish the Montane from other ecoregions, although both species can extend into the Subalpine.

Thirty containerized seedlings were planted in spring 1977 at Tent Mountain (trial TM-9). There was high mortality during the first growing season (67%). This suggests that proper care was not taken during handling and planting of the seedlings, and/or the stock was in poor condition, and/or weather and soil conditions at planting time were unfavorable. Survival after eight growing seasons was 23%, representing a drop of only 10% over seven years after the first growing season. Of the seven surviving plants in 1984, two had slight dieback on the upper branches, three had chlorotic needles, and two had aborted terminal shoot buds. Douglas fir was substantially shorter after eight seasons than any of the other conifers tested on Tent Mountain (mean height of 26 cm).

4.6.12 Green Alder (Tables 5, 6, 7, and 8; Plate 5)

Green alder is a native shrub which occurs on well- to poorly-drained sites throughout the Eastern Slopes and Boreal Ecoregions of Alberta. It is common as an understory species or an invader of open, disturbed sites such as roadsides. It has the capacity to fix atmospheric nitrogen.

Green alder container stock was planted in the fall of 1976 (trial TM-9) and in the spring of 1977 (TM-11). Both plantings consisted of 300 plants. In TM-9 survival was 54% after the first year and 51% after the second and third years. Due to some confusion over the location of the plots, this planting was not assessed in 1984. In TM-11 survival was 83% after two seasons and 78% after eight seasons. However, after the eighth season green alder had achieved a mean height of only 19 cm. Every surviving plant assessed in 1984 had heavy stem dieback and ungulate browse damage, which has kept these plants low and trailing in growth habit (see Plate 5).

Green alder occurs naturally as an upright shrub on Tent Mountain in undisturbed areas not far from the test site. However, the test site is more exposed and windier than the surrounding undisturbed areas. The dieback and low stature of the test site plants are a reflection of the harsh microclimate.

4.6.13 Green Ash (Table 2 and Appendix 3)

Green ash is a native tree in southern Canada, where it ranges from southern Saskatchewan eastward. It commonly grows along the banks of streams and on moist bottomlands. It is adapted to a wide variety of soils, from dry sands to heavy clays. In Alberta it is commonly planted along city streets as an ornamental and shade tree. It does poorly in competition with other trees and shrubs or when planted into an established grass sod. The bark of young individuals is susceptible to sunscalding.

Green ash bareroot seedlings were planted in five plots in spring 1977.

Plate 5. Green alder container seedling after eight growing seasons in trial TM-11 on Tent Mountain (August 1984). Green alder had a low, trailing growth habit on this site, in part due to heavy dieback and ungulate browse damage.

Plate 6. Lodgepole pine bareroot seedling after 12 growing seasons on Grassy Mountain (August 1984). This individual showed the low stature and flagged growth form typical of the wind damaged plants on Grassy Mountain.

Plate 7. White spruce seedling after 12 growing seasons on Grassy Mountain (August 1984). The high winds on this site are responsible for the wind-sheared appearance of this individual and may have caused the split leader.

Plate 8. White spruce seedling after 12 growing seasons at Sterco (August 1984). White spruce grew well in the coal spoils at Sterco, but some plants like this one had split leaders and aborted lateral shoot buds.

Plate 5.

Plate 6.

Plate 7.

Plate 8.

Survival after eight growing seasons was 2%. Of the five plots which were established in 1977, only six plants in one plot at Nez Perce could be located for assessment in 1984. These individuals produced only 2 to 5 chlorotic leaves each in 1984. They showed signs of heavy annual dieback. Mean plant height was only 17 cm after eight growing seasons.

4.6.14 Laurel Willow (Table 2 and Appendix 3)

This fast growing tree was introduced from Europe and is used for shelterbelts in Alberta. It is more susceptible to dieback than other willows used for shelterbelt in Alberta and generally is not recommended for use on dry sites or infertile soil.

Laurel willow was planted as bareroot stock in spring 1977 on Tent Mountain and near the Coleman Collieries Office. Most plants (95%) died during the first summer, which suggests that poor planting stock, poor handling methods, or poor planting conditions may in part account for the failure. The plots could not be found in 1984.

4.6.15 Lodgepole Pine (Table 1; Appendix 2; Plate 6)

Lodgepole pine is the predominant tree species in the Eastern Slopes and occurs in a wide range of sites. It has an adaptable rooting habit which allows it to grow in a broad range of mineral and organic soils. It is the characteristic tree of post-fire forests throughout much of the foothills. Lodgepole pine is planted in Alberta for shelterbelts, for commercial forestry, and as an ornamental.

Bareroot pine seedlings were planted on three sites in spring 1973. After 12 growing seasons overall survival in nine plots was 16%. Survival was poorest in the windy, exposed plots on Grassy Mountain and better in the more protected and lower elevation plots at Sterco and Lovett. At Sterco pine

showed good vigor and the best overall height growth of any species assessed in 1984. Survival was very high after eight growing seasons at Lovett (92%), but these plots were destroyed during reclamation and could not be assessed in 1984. The planting medium at Sterco and Lovett was gravelly waste coal, which is apparently a relatively good medium for pine growth.

The plants on Grassy Mountain were considerably shorter than those at Sterco and all plants showed signs of wind damage. Many displayed a "flagged" growth form with branches growing away from the windward side (see Plate 6). Stem dieback occurred on 69% of the surviving plants at Grassy Mountain but not on any of the plants at Sterco.

A total of 47% of all surviving plants had split leaders. Split leaders were much more common at Grassy Mountain (64%) than Sterco (9%), but occurred in all plots. Minimizing the stem damage to seedlings is an important consideration if commercial forestry is the reclamation objective. These results suggest that pine should be planted in wind-protected sites to reduce stem damage.

4.6.16 Manitoba Maple (Tables 2, 3, and 4; Appendix 3)

This tree is native to southeastern Alberta where it occurs along streams, river valleys, and ravines. It is used for shelterbelt planting and as a shade tree. It is fast growing and adapted to a wide range of soil and climatic conditions. It is sometimes considered a weed in urban areas because of its ability to establish from seed.

Four plots of bareroot seedlings were established in spring 1977. Most plants (75%) died during the first summer. In the two plots that were assessed in 1978 only 4% of the plants had survived the first winter. After eight growing seasons only the Nez Perce planting could be relocated for assessment. Survival was 2% and mean height was 38 cm. All surviving plants

exhibited leaf chlorosis and moderate to heavy stem dieback.

Manitoba maple was also planted as bareroot stock on Tent Mountain in 1976 (trial TM-5). Survival was 87% after the two growing seasons but dropped to 11% after the ninth season. Mean height was only 12 cm and all plants had heavy dieback after nine seasons, which suggests that Manitoba maple is poorly adapted to this Subalpine site.

4.6.17 Native Willow (Table 2 and Appendix 3)

In spring 1977 bareroot seedlings of an unknown species of willow from Fort McMurray were planted at Coal Valley, Tent Mountain, and Racehorse. After the first summer survival ranged from 0% at Racehorse to 70% at Coal Valley. However, by the next year all plants had died and/or could not be found.

4.6.18 Northwest Poplar (Table 2 and Appendix 3)

Northwest poplar is a natural hybrid between plains cottonwood and balsam poplar. It was introduced as a male clone by the Northwest Nursery of Valley City, North Dakota. It is fast growing and desirable for shelterbelt planting in the plains region of Alberta.

Northwest poplar was planted in four locations as bareroot stock in spring 1977. After eight growing seasons only the plot at Nez Perce could be relocated for assessment. Survival was 11% and all plants had some degree of stem dieback. Mean plant height was 39 cm. Many plants had slightly chlorotic leaves and a few had been browsed by ungulates.

4.6.19 Paper Birch (Tables 5 and 6)

Paper birch is native in Alberta, where it occurs frequently but not abundantly in the Boreal Foothills and Mixedwood Ecoregions. It is less common in the Boreal Uplands and Northlands Ecoregions. It is planted as an

ornamental.

Three hundred containerized seedlings were planted on Tent Mountain in fall 1976 (trial TM-9). Survival after the first, second, and third growing seasons was 59, 52, and 44% respectively. The plants showed a reduction in height from the first to second and second to third seasons due to dieback. Because of confusion over the location of the plots, these plantings were not assessed in 1984.

4.6.20 Red Elder (Tables 3 and 4)

Red elder is a tall shrub with decorative red fruit. It is commonly planted in Alberta for visual screening. Although it is cold hardy, the branches of red elder are susceptible to tip kill.

One hundred bareroot seedlings were planted on Tent Mountain in spring 1976 (trial TM-5). Survival was 19% after the second and third growing seasons and only 2% after the ninth season. Each of the three surviving plants in 1984 was slightly chlorotic and had heavy dieback.

4.6.21 Russian Olive (Table 2 and Appendix 3)

Russian olive is a tall shrub introduced from southeastern Europe. It is planted in hedgerows for shelterbelt protection in southeastern Alberta. It is susceptible to dieback and winter kill in northwestern Alberta and may not be winter hardy enough to be useful in the foothills.

Russian olive was planted on four sites as bareroot stock in spring 1977. Overall survival was 25% after one growing season. Of the plots that could be relocated, survival was 22% after two seasons and 70% after eight seasons. The increase in survival from the second to eighth seasons is explained by the fact that the Coal Valley plot, which had 70% survival, was missed during the 1978 assessment but was the only plot that could be found in 1984. All

surviving plants at Coal Valley after eight growing seasons had some amount of stem dieback.

4.6.22 Siberian (Manchurian) Elm (Table 2 and Appendix 3)

This fast growing tree was introduced from central Asia. It is used in farmstead shelterbelts and, when planted close together, forms a tall hedge which reacts well to repeated shearing. It is very popular in field shelterbelts in the Dakotas. Siberian elm is used less commonly today than in the past in the Canadian prairies because it is short-lived and sensitive to tip kill.

Siberian elm bareroot seedlings were planted in five locations in spring 1977. Survival was relatively high after the second growing season (46%). By the eighth season, however, one of the plots had been destroyed by reclamation activities and the remaining four could not be located.

4.6.23 Siberian Larch (Tables 3, 4, 5, and 6)

Siberian larch is a fast growing, introduced tree that is used as an ornamental and for shelterbelt planting in Alberta. Although it loses its foliage during the winter it is considered a good windbreak builder. Its major limitation is that it is difficult to transplant and establish.

One hundred bareroot and 50 containerized seedlings were planted on Tent Mountain in spring 1976 (trial TM-5) and fall 1976 (TM-9), respectively. Survival in TM-5 was 51% after the second growing season and 48% after the ninth season. Thus, mortality was high initially but has been very low over the past seven years. Survival in TM-9 was still high (84%) after eight growing seasons.

Siberian larch was the tallest species assessed on Tent Mountain in 1984. Mean height in TM-5 was 73 cm and in TM-9 was 55 cm. Of the surviving plants

in TM-5, 29% had slight to moderate stem dieback and 38% had split leaders in 1984. In TM-9 26% had slight dieback and 7% had split leaders. Many of the plants in both plots had chlorotic needles with necrotic tips when assessed 20 August. However, this may have been early signs of normal needle senescence for this deciduous conifer.

4.6.24 Speckled Alder (Tables 5 and 6)

Speckled alder is native in eastern Canada where it occurs along streams and in swampy places. It is closely related to river alder (Alnus tenuifolia) which occurs in Alberta. The speckled alder planting stock was grown at OPTN specifically for this study and is generally not grown commercially in Alberta.

Ninety containerized seedlings of speckled alder were planted on Tent Mountain in fall 1976 (trial TM-9). Mortality was high during the first year (80%) but has been low ever since. Survival after eight growing seasons was 14% and mean height was only 17 cm. Similar to green alder in TM-11, all surviving individuals of speckled alder in 1984 had heavy stem dieback and were heavily browsed by ungulates.

4.6.25 Vernirubens Poplar (Table 2 and Appendix 3)

Vernirubens poplar was a Euramerican hybrid which was tested at PFRA for use in shelterbelts. It was found unsuitable and is no longer produced because of its sensitivity to winter killing and susceptibility to canker diseases.

Bareroot seedlings were planted in four plots in spring 1977. Survival was 27% after the first summer. None of the plants survived the first winter.

4.6.26 Walker Poplar (Table 2 and Appendix 3)

Walker poplar was developed by John Walker at PFRA as an open-pollinated

female clone of plains cottonwood (Populus deltoides). It is fast growing and slightly sensitive to tip kill (winter kill in northern regions) because of its long growing season. It is resistant to poplar bud gall mite and most cankering diseases.

Walker poplar was planted as bareroot stock in four plots in spring 1977. Survival was 18% after the first growing season and 0% after the second.

4.6.27 White Spruce (Tables 1, 3, and 4; Appendix 2; Plates 7 and 8)

White spruce is native in Alberta and common throughout the Eastern Slopes, except in the Subalpine where it is rare. It is probably the most frequent evergreen tree planted for shelterbelt in Alberta. It is also planted as an ornamental and for commercial forestry. It is adapted to a wide range of soils but grows best in moist, well-drained, fertile soils.

After 12 growing seasons survival of the bareroot stock was 44% (based on 12 plots) compared with 15% for the container stock (based on 8 plots). Overall survival was 35%.

Similar to lodgepole pine, white spruce had higher survival and much better growth and vigor at Sterco than Grassy Mountain. Most plants at Grassy Mountain were wind damaged with many showing stem dieback and a flagged growth form (Plate 7). A few plants had a wind-sheared, krummholtz appearance. In 1984 84% of the surviving plants on Grassy Mountain had split leaders while 40% of those at Sterco and Lovett had split leaders. Thus white spruce, like lodgepole pine, is susceptible to growth inhibition and stem damage on windy sites such as Grassy Mountain.

The amount of insect damage and leaf chlorosis found on the plants varied widely. Many of the plants at Sterco and Lovett had aborted lateral shoot buds that appeared to be caused by an insect (Plate 8). This was less common in the Grassy Mountain plantings. However, the Grassy Mountain plants were

more chlorotic than those at Lovett or Sterco, which suggests that the Grassy Mountain spoils were less fertile.

White spruce was also planted as bareroot stock in 1976 on Tent Mountain (trial TM-5). Survival was still high (76%) after nine growing seasons. However, 24% of the survivers had slight to moderate dieback, 66% showed slight insect damage, and 29% had split leaders.

5. CONCLUSIONS

Plant survival after eight or nine years was poor in many plots and good in only a few plots. Yet species with low survival rates are not necessarily unadapted to the test site environments. Some of the 1977 planting stock was in poor condition at planting time, and pre-stressed plants tend to have low survival rates regardless of their adaptation to the test site conditions. Also, mortality due to competition with seeded grasses and legumes was probably high in some plots. Furthermore, the handling methods and soil conditions at planting time may have been poor. Thus, in these plantings a low survival rate is not conclusive evidence of poor adaptation.

Similarly, high survival does not indicate always that a species will grow and be vigorous and fulfill its reclamation objective. For example, green alder had good survival on Tent Mountain but was kept very low by dieback and browsing. It may never develop into an upright shrub in such conditions.

The height growth, vigor information, and survival rates do, however, give some indication of the adaptation of the species to the test site environments. In an effort to narrow the field of candidate species for future research, the following statements on species adaptation are offered; although the data on which they are based is not adequate and is sometimes contradictory.

1. Although the survival rate was high in some cases, no species had good height growth or vigor on the Montane or Subalpine test sites after a minimum of eight growing seasons.

2. Several species had fair to good survival rates on Tent Mountain or Racehorse and may have potential for use on protected Subalpine mine site: caragana, Colorado spruce, green alder, Siberian larch, and white spruce.
3. The following species had very low survival rates and poor vigor on Tent Mountain or Racehorse and are probably poorly adapted to subalpine mine site: Asian rose, balsam poplar, Manitoba maple, mixed willow, red elder, and speckled alder.
4. Caragana, lodgepole pine, and white spruce had fair to good survival rates at Nez Perce or Grassy Mountain, and thus they may have potential for use on protected Montane mine site. Lodgepole pine and white spruce had poor height growth and stem form on Grassy Mountain and appear poorly adapted to windy, Montane mine site.
5. The following species had very low survival and poor vigor at Nez Perce or the Coleman Collieries Office, and thus they are probably poorly adapted to Montane mine site: Bassford willow, green ash, northwest poplar.
6. Lodgepole pine and white spruce had good survival, height growth, and vigor after 12 years in some plots at Lovett and Sterco, and thus they are probably well adapted for growth on mine sites in the Boreal Foothills and Boreal Uplands Ecoregions. Russian olive had good survival after eight years at Coal Valley, but it had moderate to heavy dieback and appears to be incompletely adapted to the climate on this Boreal Foothills/Uplands site.
7. The following species could not be found for assessment in 1984, probably because mortality in the plots was very high: acuteleaf willow, American elm, amur maple, laurel willow, native willow,

Siberian elm, vernirubens poplar, and Walker poplar.

8. Buffaloberry could not be evaluated for long-term adaptability because the plot was destroyed during site reclamation.
9. Browsing by ungulates was moderate to heavy on the following species and appeared to limit their growth and development: aspen, balsam poplar, green alder, and speckled alder. Many other species, especially the willows and poplars, were lightly browsed.

6. RECOMMENDATIONS

1. Lodgepole pine and white spruce showed stem damage and reduced height growth when grown on wind-exposed mine sites. Wind exposure could be reduced during the recontouring phase of mining by leaving the spoil surface "rough" and creating wind breaks where possible. On windy sites woody species should be planted in protected microsites, such as slope bases, leeward slopes, and snow accumulation areas.

2. This study suggests that browsing by ungulates can severely limit the growth and development of some woody species. Fencing newly planted areas may be necessary to limit ungulate access until plants are well established. Mining companies may wish to postpone planting palatable woody species on active mines in order to avoid attracting animals and thus creating on-site animal management problems.

3. Plant survival and vigor both within and among species varied widely from area to area in this study. This suggests that research on plant adaptability and suitability for given reclamation objectives should be site-specific.

Appendix 1

PLOT DESCRIPTIONS AND PLANTING ESTABLISHMENT DETAILS

Site	El.(m)	Location	Year of Establishment	Plot No.	Species	Stock Type[1]	No. Planted	Status in 1984[2]
Lovett	1372	SW 16-47-19-W5	1973	1	lodgepole pine	br.	100	D
				2	white spruce	br.	100	D
				3	white spruce	cont.	100	D
				4	white spruce	br.	100	A
				5	white spruce	cont.	100	D
				6	lodgepole pine	br.	100	D
				7	lodgepole pine	br.	100	D
Sterco	1433	NE 34-47-20-W5	1973	8 or 9	lodgepole pine	br.	100	A
				10	white spruce	br.	100	A
				11	white spruce	br.	100	A
				12	white spruce	br.	100	A
				13	white spruce	cont.	100	A
Grassy Mountain	1585	NE 23-8-4-W5	1973	28	lodgepole pine	br.	100	A
				29	white spruce	br.	100	A
Grassy Mountain	1646	SW 25-8-4-W5	1973	30	white spruce	br.	100	A
				31	lodgepole pine	br.	100	A
				32	white spruce	br.	100	A
				33	lodgepole pine	br.	100	A
				34	white spruce	cont.	100	A
				35	white spruce	cont.	100	NF
Grassy Mountain	1890	NE 25-8-4-W5	1973	36	lodgepole pine	br.	100	A
				37	white spruce	br.	100	A
				38	white spruce	cont.	100	A
				39	white spruce	cont.	100	A
				40	lodgepole pine	br.	100	A
				41	white spruce	br.	100	A

Appendix 1 (continued)

Site	El.(m)	Location	Year of Establishment	Plot No.	Species	Stock Type[1]	No. Planted	Status in 1984[2]
				42	white spruce	cont.	100	A
				43	white spruce	br.	100	A
				44	white spruce	br.	100	A
Coal Valley	1408	NE 29-47-20-W5	1977	60	northwest poplar	br.	114	NF
				61	mixed willow	br.	121	A
				62	green ash	br.	359	NF
				63	Manitoba maple	br.	89	NF
				64	Walker poplar	br.	110	NF
				65	amur maple	br.	37	NF
				66	Siberian elm	br.	65	NF
				67	native willow (Ft. McMurray)	br.	62	NF
				68	American elm	br.	161	NF
				69	acuteleaf willow	br.	157	NF
				70	vernirubens poplar	br.	143	NF
				71	Russian olive	br.	53	A
Tent Mountain	1859	SE 23-7-6-W5	1977	72	mixed willow	br.	150	NF
				73	vernirubens willow	br.	144	NF
				74	Manitoba maple	br.	110	A
				75	Laurel willow	br.	126	NF
				76	native willow	br.	123	NF
				77	northwest poplar	br.	150	NF
				78	Russian olive	br.	105	NF
				79	Manitoba maple	br.	120	NF
				80	green ash	br.	244	NF
				81	Siberian elm	br.	98	NF
				82	Bassford willow	br.	150	A
				83	balsam poplar	br.	190	A
Racehorse	1981	7-10-4-W5	1977	84	mixed willow	br.	165	A
				85	caragana	br.	230	A

Appendix 1 (continued)

Site	El.(m)	Location	Year of Establishment	Plot No.	Species	Stock Type[1]	No. Planted	Status in 1984[2]
				86	Bassford willow	br.	162	A
				87	Russian olive	br.	150	NF
				88	balsam poplar & Russian olive	br.	150	NF
				89	native willow	br.	150	NF
				90	Siberian elm	br.	117	NF
				91	acuteleaf willow	br.	145	NF
				92	northwest poplar	br.	152	NF
				93	mixed poplar	br.	158	A
				94	Russian olive	br.	92	NF
				95	amur maple	br.	95	NF
				96	green ash	br.	253	NF
				97	vernirubens poplar	br.	144	NF
Nez Perce	1753	E 1/2-29-8-4-W5	1977	98	amur maple	br.	91	NF
				99	acuteleaf willow	br.	153	NF
				100	mixed poplar	br.	150	NF
				101	American elm	br.	202	NF
				102	Walker poplar	br.	160	NF
				103	green ash	br.	258	A
				104	mixed poplar	br.	194	A
				105	Manitoba maple	br.	130	NF
				106	balsam poplar	br.	150	NF
				107	Walker poplar	br.	165	NF
				108	American elm	br.	190	NF
				109	Siberian elm	br	96	NF
				110	mixed willow	br.	146	NF
				111	northwest poplar	br.	145	A
				112	caragana	br.	246	A
				113	Walker poplar	br.	133	NF
Coleman Collieries	1374	N 1/2-7-8-4-W5	1977	114	laurel leaf willow	br.	151	NF
				115	Bassford willow	br.	135	A

Appendix 1 (continued)

Site	El.(m)	Location	Year of Establishment	Plot No.	Species	Stock Type[1]	No. Planted	Status in 1984[2]
Office				116	American elm	br.	194	NF
				117	mixed poplar	br.	144	NF
Coleman Collieries Office	1341	N 1/2-6-8-4-W5	1977	118	mixed willow	br.	137	D
				119	green ash	br.	240	D
				120	Russian olive	br.	97	D
				121	Siberian elm	br.	98	D
				122	caragana	br.	209	D
				123	buffaloberry	br.	304	D
				124	caragana	br.	42	D
				125	vernirubens poplar	br.	142	D
				126	caragana	br.	256	D
Tent Mountain	2103	14-7-6-W5	1976	TM-5	Asian rose	br.	99	dead
				TM-5	Colorado spruce	br.	50	A
				TM-5	Manitoba maple	br.	120	A
				TM-5	red elder	br.	100	A
				TM-5	Siberian larch	br.	100	A
				TM-5	white spruce	br.	50	A
				TM-9	American elm	cont.	300	A
				TM-9	Douglas fir	cont.	30	A
				TM-9	green alder	cont.	300	A
				TM-9	paper birch	cont.	300	A
				TM-9	Siberian larch	cont.	50	A
				TM-9	speckled alder	cont.	90	A
				TM-11	aspen	cont.	300	A
				TM-11	green alder	cont.	300	A

[1] br. = bareroot stock; cont. = container stock
[2] A = plot had some living plants in 1984; D = plot was destroyed; dead = all plants died; NF = plot not found

Appendix 2

SPECIES SURVIVAL RATE, HEIGHT, AND HEIGHT GROWTH IN PLOTS ESTABLISHED IN 1973

Site	Plot No.	Species/ Stock Type[1]	Survival (%)[2] 1973	1978	1980	1984	Height (cm) 1984 $\bar{x}$	SE	5 yr height Growth (cm/5 yr) 1980-84 $\bar{x}$	SE
Lovett	1	Pl/br.	98	93	91	D[3]	D	D	D	D
	2	Sw/br.	100	77	85	D	D	D	D	D
	3	Sw/cont.	94	20	40	D	D	D	D	D
	4	Sw/br.	97	92	93	86	67	4	47	2
	5	Sw/cont.	63	17	24	D	D	D	D	D
	6	Pl/br.	95	94	94	D	D	D	D	D
	7	Pl/br.	96	95	91	D	D	D	D	D
Sterco	8 or 9	Pl/br.	89	NA	23	23	191	9	123	6
	10	Sw/br.	100	NA	89	89	230	6	143	3
	11	Sw/br.	95	NA	70	67	113	5	82	3
	12	Sw/br.	91	NA	59	56	127	6	91	4
	13	Sw/cont.	69	NA	27	34	128	7	94	5
Grassy Mountain	28	Pl/br.	36	13	NA	7	47	6	33	2
	29	Sw/br.	84	38	NA	1	10	–	NA	NA
	30	Sw/br.	57	1	NA	1	91	–	35	–
	31	Pl/br.	44	6	NA	2	73	4	41	13
	32	Sw/br.	79	NF	NA	49	30	2	20	1
	33	Pl/br.	66	31	NA	27	48	10	55	8
	34	Sw/cont.	78	27	NA	27	29	3	19	2
	35	Sw/cont.	21	NF	NA	NF	NF	NF	NF	NF
	36	Pl/br.	50	33	NA	28	72	6	52	4
	37	Sw/br.	83	52	NA	47	33	2	24	2
	38	Sw/cont.	43	13	NA	10	28	4	26	4
	39	Sw/cont.	10	1	NA	1	44	–	31	–
	40	Pl/br.	31	12	NA	10	54	8	36	6
	41	Sw/br.	82	62	NA	59	30	2	26	2
	42	Sw/cont.	40	4	NA	3	21	8	32	–
	43	Sw/br.	35	15	NA	14	18	2	17	2
	44	Sw/br.	73	19	NA	20	23	3	22	4

[1] Pl = lodgepole pine; Sw = white spruce; br. = bareroot stock; cont. = container stock

[2] 1973 and 1978 data were obtained from AFS records; 1980 data was obtained from Luscar Sterco (1977) Ltd.

[3] [illegible] plo[illegible]estr[illegible]d; [illegible] pl[illegible]or p[illegible]mete[illegible]ot [illegible]sse[illegible] NF [illegible]ot [illegible]fou[illegible]

Appendix 3

SPECIES SURVIVAL RATE, HEIGHT AND ANNUAL HEIGHT GROWTH IN PLOTS ESTABLISHED IN 1977

Site	Plot No.	Species	Survival (%)[1]			Height (cm) 1984		Annual Height Growth (cm/yr) 1984	
			1977	1978	1984	$\bar{x}$	SE	$\bar{x}$	SE
Coal Valley	60	northwest poplar	54	NF[2]	NF	NF	NF	NF	NF
	61	mixed willow	79	62	74	36	1	22	1
	62	green ash	80	16	NF	NF	NF	NF	NF
	63	Manitoba maple	66	NF	NF	NF	NF	NF	NF
	64	Walker poplar	53	NF	NF	NF	NF	NF	NF
	65	amur maple	5	NF	NF	NF	NF	NF	NF
	66	Siberian elm	51	NF	NF	NF	NF	NF	NF
	67	native willow (Ft. McMurray)	76	NF	NF	NF	NF	NF	NF
	68	American elm	70	NF	NF	NF	NF	NF	NF
	69	acuteleaf willow	92	NF	NF	NF	NF	NF	NF
	70	vernirubens poplar	41	NF	NF	NF	NF	NF	NF
	71	Russian olive	45	NF	70	51	3	15	1
Tent Mountain	72	mixed willow	13	NA	NF	NF	NF	NF	NF
	73	vernirubens poplar	32	NA	NF	NF	NF	NF	NF
	74	Manitoba maple	39	NA	2	38	22	11	6
	75	laurel willow	11	NA	NF	NF	NF	NF	NF
	76	native willow	40	0	NF	NF	NF	NF	NF
	77	northwest poplar	70	66	NF	NF	NF	NF	NF
	78	Russian olive	24	0	NF	NF	NF	NF	NF
	79	Manitoba maple	6	5	NF	NF	NF	NF	NF
	80	green ash	29	14	NF	NF	NF	NF	NF
	81	Siberian elm	59	NA	NF	NF	NF	NF	NF
	82	Bassford willow	24	4	< 1	40	-	40	-
	83	balsam poplar	47	27	< 1	81	-	23	-
Racehorse	84	mixed willow	70	50	10	29	4	18	3
	85	caragana	40	24	30	40	2	13	1
	86	Bassford willow	74	50	38	27	1	19	1
	87	Russian olive	0	NF	NF	NF	NF	NF	NF

Appendix 3 (continued)

Site	Plot No.	Species	Survival (%)[1] 1977	1978	1984	Height (cm) 1984 $\bar{x}$	SE	Annual Height Growth (cm/yr) 1984 $\bar{x}$	SE
	88	balsam poplar & Russian olive	0	NF	NF	NF	NF	NF	NF
	89	native willow	0	NF	NF	NF	NF	NF	NF
	90	Siberian elm	22	NF	NF	NF	NF	NF	NF
	91	acuteleaf willow	38	NF	NF	NF	NF	NF	NF
	92	northwest poplar	62	NF	NF	NF	NF	NF	NF
	93	mixed poplar	79	80	27	24	1	6	1
	94	Russian olive	50	NF	NF	NF	NF	NF	NF
	95	amur maple	2	NF	NF	NF	NF	NF	NF
	96	green ash	34	NF	NF	NF	NF	NF	NF
	97	vernirubens poplar	13	0	NF	NF	NF	NF	NF
Nez Perce	98	amur maple	0	NA	NF	NF	NF	NF	NF
	99	acuteleaf willow	4	NA	NF	NF	NF	NF	NF
	100	mixed poplar	13	0	NF	NF	NF	NF	NF
	101	American elm	52	31	NF	NF	NF	NF	NF
	102	Walker poplar	4	0	NF	NF	NF	NF	NF
	103	green ash	54	26	2	17	3	17	3
	104	mixed poplar	18	17	6	49	6	23	4
	105	Manitoba maple	3	3	NF	NF	NF	NF	NF
	106	balsam poplar	8	15	NF	NF	NF	NF	NF
	107	Walker poplar	3	0	NF	NF	NF	NF	NF
	108	American elm	44	48	NF	NF	NF	NF	NF
	109	Siberian elm	53	38	NF	NF	NF	NF	NF
	110	mixed willow	37	16	NF	NF	NF	NF	NF
	111	northwest poplar	17	16	11	39	2	17	2
	112	caragana	60	41	55	65	2	16	1
	113	Walker poplar	23	10	NF	NF	NF	NF	NF
Coleman Office	114	laurel willow	0	NF	NF	NF	NF	NF	NF
	115	Bassford willow	23	13	< 1	60	-	7	-
	116	American elm	12	2	NF	NF	NF	NF	NF

Appendix 3 (continued)

Site	Plot No.	Species	Survival (%)[1] 1977	1978	1984	Height (cm) 1984 $\bar{x}$	SE	Annual Height Growth (cm/yr) 1984 $\bar{x}$	SE
	117	mixed poplar	4	3	NF	NF	NF	NF	NF
Coleman	118	mixed willow	51	45	D	D	D	D	D
Plant	119	green ash	51	62	D	D	D	D	D
	120	Russian olive	51	46	D	D	D	D	D
	121	Siberian elm	50	42	D	D	D	D	D
	122	caragana	61	56	D	D	D	D	D
	123	buffaloberry	64	52	D	D	D	D	D
	124	caragana	65	NF	D	D	D	D	D
	125	vernirubens poplar	21	NF	D	D	D	D	D
	126	caragana	51	NF	D	D	D	D	D

[1] 1977 and 1978 data were obtained from AFS records
[2] NA = plot not assessed; NF = plot not found; D = plot destroyed

Appendix 4

COMMON AND SCIENTIFIC NAMES

Common Name	Scientific Name
acuteleaf willow	Salix acutifolia Willd.
American elm	Ulmus americana L.
amur maple	Acer ginnala Maxim.
Asian rose	Rosa rugosa Thunb.
aspen	Populus tremuloides Michx.
balsam poplar	Populus balsamifera L.
Bassford willow	Salix fragilis var. basfordiana Redher
buffaloberry	Shepherdia argentea Nutt.
caragana	Caragana arborescens Lam.
Colorado spruce	picea pungens engelm.
Douglas fir	Pseudotsuga menziesii (Mirb.) Franco
green alder	Alnus crispa (Ait.) Pursh
green ash	Fraxinus pennsylvanica Marsh. var. subintegerrima (Vahl) Fern.
laurel willow	Salix pentandra L.
lodgepole pine	Pinus contorta Dougl. var. latifolia Engelm.
Manitoba maple	Acer negundo L.
native willow	Salix sp.
northwest poplar	Populus deltoides Marsh. x P. balsamifera L.
paper birch	Betula papyrifera Marsh.
red elder	Sambucus racemosa L.
Russian olive	Elaeagnus angustifolia L.
Siberian elm	Ulmus pumila L.
Siberian larch	Larix sibirica Ledeb.
speckled alder	Alnus rugosa (Du Roi) Spreng.
vernirubens poplar	Populus x Euramericana (Dode) Guinier c.v. vernirubens
Walker poplar	Populus deltoides Marsh. x P. sp.
white spruce	Picea glanca (Moench) Voss.

LIST OF REFERENCES

Alberta Department of Environment. 1982. Climate of Alberta: Tables of Temperature, Precipitation, and Sunshine. Edmonton.

King, P.J. 1980. Tent Mountain Reclamation Demonstration Plantings 1979. Edmonton: Alberta Forest Service, Alberta Energy and Natural Resources.

Mihajlovich, M.M., and W.B. Russell. 1980. Tent Mountain Reclamation Demonstration Plantings 1977 and 1978. Edmonton: Alberta Forest Service, Alberta Energy and Natural Resources.

Oosterhuis, H.T. 1983. Shelterbelt Planting and Farmstead Beautification. Edmonton: Plant Industry Division, Alberta Agriculture.

Selner, J. 1973. Surface Mine Reclamation Research in Alberta. Progress report for 1973. Edmonton: Alberta Energy and Natural Resources.

Selner, J. 1974. "Reclamation Afforestation in the Green Zone of Alberta." In Hocking D., and W.R. MacDonald (eds.). Proceedings of Workshop on Reclamation of Disturbed Lands in Alberta. March 27-28. Alberta Department of Environment, Canada Department of Environment, Northern Forest Research Centre. Edmonton. Information Report NOR-X-116, pp. 94-97.

Selner, J., P. King, and D. Hildebrandt. 1977. Progress Report for Tent Mountain Coal-Mined Land Reclamation Trials (1975-76). Edmonton: Alberta Forest Service, Alberta Energy and Natural Resources. (ENR Report No. 32).

Strong, W.L., and K.R. Leggat. 1981. Ecoregions of Alberta. Edmonton: Resource Evaluation and Planning Division, Alberta Energy and Natural Resources.